DETERMINING A RELATIVE MOVEMENT OF A CHASSIS AND A VEHICLE BODY OF A WHEELED VEHICLE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a U.S. national stage application of International Application No. PCT/EP2004/052716 filed October 29, 2004, which designates the United States of America, and claims priority to German application number DE 103 58 334.3 filed December 12, 2003, the contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

[0002] The invention relates to an arrangement and a method for determining a relative movement of a chassis and a vehicle body of a wheeled vehicle, wherein said vehicle body is movably connected to the chassis.

[0003] Suspension travel of a spring-loaded connection between a vehicle body and a chassis, or height levels of the relative movement between the chassis and the vehicle body, for example, are used as input variables of systems for adjusting an absorption of the relative movement and/or other systems for adjusting and/or monitoring properties of the vehicle.

[0004] In particular, the invention relates to a combination of the arrangement with at least one of the aforementioned systems or with any combination of such systems.

BACKGROUND

[0005] In order to determine the suspension travel or height levels the prior art discloses measuring, in the vicinity of the wheels, a length of a dimension between the chassis and the vehicle body or the change in a position of a measuring point. For example, four-wheeled vehicles always have one such measuring sensor per wheel or three such measuring sensors, these being designated as height-level sensors in the following.

[0006] However, height-level sensors are relatively expensive and subject to significant stresses during their deployment in a motor vehicle. This is due in particular to adverse mechanical effects e.g. from particles and stones which are swirled up into the region between wheels and vehicle body during travel, and from humidity and temperature fluctuations.

SUMMARY

[0007] The present invention addresses the problem of specifying an arrangement and a method which allow a reliable and economical determination of a relative movement of a chassis and a vehicle body of a wheeled vehicle, said vehicle body being movably connected to the chassis.

[0008] In order to determine a relative movement of a chassis and a vehicle body of a wheeled vehicle, said vehicle body being movably connected to the chassis, it is proposed

- within the wheeled vehicle to measure three respectively perpendicular linear accelerations of the wheeled vehicle and at least two rotational speeds, each relating to a rotational movement or a component of a rotational movement about a coordinate axis of the wheeled vehicle, wherein the at least two coordinate axes run perpendicularly to each other, and
- to determine a momentary movement position of the relative movement using the three linear accelerations and the at least two rotational speeds (in particular repeated).

[0009] The following is additionally proposed: An arrangement for determining a relative movement of a chassis and a vehicle body of a wheeled vehicle, said vehicle body being movably connected to the chassis, which arrangement has

- a measuring entity which is arranged or can be arranged in the wheeled vehicle, wherein the measuring entity is configured to measure three respectively perpendicular linear accelerations of the wheeled vehicle and at least two rotational speeds, each relating to a rotational movement or a component of a rotational movement about a coordinate axis of the wheeled vehicle, wherein the at least two coordinate axes run perpendicularly to each other, and
- an analysis entity which is combined with the measuring entity and is configured to determine a momentary movement position of the relative movement using the

three linear accelerations and the at least two rotational speeds.

[0010] The measuring entity preferably has acceleration sensors for measuring the three linear accelerations and rotational speed sensors for measuring the at least two rotational speeds, wherein the acceleration sensors and the rotational speed sensors can be parts of a preprepared hardware unit which is configured for installation in the wheeled vehicle. This unit is a special embodiment of a so-called Inertial Measurement Unit (IMU). The IMU is intended for attachment at or in the vicinity of the center of gravity of a wheeled vehicle, for example. Therefore the center of gravity of the wheeled vehicle or of a body of a wheeled vehicle preferably lies within the unit.

[0011] Moreover, it is preferable if the three linear accelerations can be measured by the measuring entity as measured variables which are linearly independent of each other. The directions of the accelerations or acceleration components which are in each case captured by the acceleration sensors preferably form the axes of a three-dimensional right-angled system of coordinates.

[0012] A corresponding preference applies to the orientation of the at least two coordinate axes, in relation to which components of the rotational vector of a rotational movement of the vehicle are measured. In other words, the measuring entity is configured such that the at least two axes run perpendicularly to each other as a pair in each case.

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CLEAN VERSION

[0013] The measuring entity can include a separate sensor for each measured variable, for example. However, there are also sensors which simultaneously measure two of the cited measured variables (e.g. two accelerations or two rotational speeds).

[0014] In particular, the measuring sensors of the measuring entity for measuring the rotational speeds and for measuring the linear accelerations are attached to the vehicle body which can move relative to a vehicle chassis. In this way, the solution according to the invention allows at least some of the sensors and preferably all sensors to be arranged at a location which is protected from environmental influences. The region of the center of gravity of the wheeled vehicle or the region of the center of gravity of a vehicle body is suitable for this purpose in many cases.

[0015] Depending on the orientation of the vehicle, acceleration sensors measure a measured variable which is influenced by the force of gravity. When the vehicle is stationary, the acceleration sensor measures only the effects of the force of gravity. The real acceleration does not then appear in the variable as measured.

[0016] In this description, the dynamic acceleration variable which is changed by the force of gravity is designated as the effective acceleration variable. The effective acceleration values are preferably used when determining the relative movement of the chassis and the vehicle body. Therefore the gravity or gravitational force which actually also influences the relative movement of the

chassis and the vehicle body is taken into consideration. Correction of the effective acceleration values, which could be achieved e.g. by integrating the measured rotational speeds and determining the orientation of the vehicle relative to an earth-fixed system of coordinates, is not necessary. Rather, the gravitational force affects the vehicle in different ways depending on the travel situation (e.g. during travel on roadways having different inclines) and should also be taken into consideration.

[0017] As a result of using the at least two rotational speeds and the three accelerations of the vehicle, it is also possible to establish the relative movement between the vehicle body and the chassis without height-level sensors. This also applies when cornering and/or when traveling on inclined roadways or inclined subsurfaces (inclined laterally and/or forwards).

[0018] It is possible to economize at least part of the cost-intensive height-level sensors. On the other hand, the sensors for measuring the linear accelerations and rotational speeds can also be used for other purposes (e.g. as input variables for further electronic systems such as an anti-blocking system or the electronic stability program). Moreover, it is possible to monitor existing height-level sensors with regard to reliably determining the suspension travel and/or the height positions. If the height-level sensors temporarily supply implausible measured values, it can be decided - perhaps using further measured variables (e.g. travel speed, angle of lock) - whether systems which use the

height levels as input variables can still be operated. For example, it might be decided that the height levels (or equivalent variables) which are determined in the manner according to the invention can still be used, since the height-level sensors were disrupted by environmental influences.

[0019] In particular, a plurality of momentary movement positions are calculated using the at least two rotational speeds and the three linear accelerations, wherein each of the movement positions is a measure for a distance between the vehicle body and at least one wheel of the chassis.

[0020] The momentary movement position is preferably calculated with reference to a spring suspension, in particular a spring suspension which is moderated, between at least one of the wheels of the wheeled vehicle and a vehicle body.

[0021] In particular, the analysis entity can include a calculation unit which is configured to calculate the relative movement. The calculation unit includes e.g. a microprocessor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The invention is now explained in greater detail with reference to exemplary embodiments. In this case, reference is made to the appended schematic drawing and a preferred embodiment is described. Identical reference signs in the drawing designate units or entities which are

identical, functionally identical or equivalent. In the individual figures in the drawing,

Figure 1 shows a road motor vehicle including an arrangement for determining a relative movement between a chassis and a vehicle body;

Figure 2 shows a configuration of the analysis entity which is illustrated in Figure 1, in combination with a measuring entity;

Figure 3 shows the measuring entity which is illustrated in Figure 1, in a shared housing with the analysis entity;

Figure 4 shows a side view of a model of a road motor vehicle including a chassis and a vehicle body which is connected to the chassis via a moderated spring suspension;

Figure 5 shows the model as per Figure 4 from the front;

Figure 6 shows an illustration of a road motor vehicle for clarifying dimensions and angles;

Figure 7 shows an example for a configuration of the measuring entity which is illustrated in Figure 1.

DETAILED DESCRIPTION

[0023] The road motor vehicle 20 illustrated in Figure 1 has two front wheels and two rear wheels, of which the right-hand front wheel is designated using the reference sign 22 and the right-hand rear wheel is designated using the reference sign 24. The front wheels are assigned to a front axle 26. The rear wheels are assigned to a rear axle 27. The wheels which

are assigned to an axle rotate coaxially when the road motor vehicle 20 is traveling in a straight line, i.e. they have a shared axis of rotation. A measuring entity 1 which is connected to an analysis entity 9 is arranged in the road motor vehicle 20.

[0024] As illustrated in Figure 7, the measuring entity 1 includes e.g. an acceleration measuring entity 3 and a rotational speed measuring entity 4. The measuring entity 1 is in particular a ready-made structural unit, wherein the corresponding measuring sensors for measuring the accelerations and rotational speeds are arranged in fixed positions relative to each other in the unit. The structural unit is preferably defined for attachment at or in the vicinity of the center of gravity of a motor vehicle, wherein a specific alignment within the vehicle is intended.

[0025] In particular, the acceleration measuring entity 3 has three linear acceleration sensors 31, 32, 33 (Figure 7) which are arranged such that one of the acceleration sensors in each case measures an acceleration or acceleration component of the vehicle in the direction of the axes of a cartesian system of coordinates, wherein the x-axis points forwards in the longitudinal direction of the vehicle, the y-axis is oriented perpendicularly to the longitudinal axis, and the z-axis (in the case of a vehicle which is oriented horizontally) extends vertically upwards. Such a system of coordinates is illustrated schematically in Figure 6. This figure shows a road motor vehicle 20 including two steerable front wheels 21, 22 and two non-steerable rear wheels 23, 24.

In the state which is illustrated, the front wheels are steered to the left and exhibit an angle of lock of δ_L (left-hand front wheel 21) or δ_R (right-hand front wheel 22) in relation to the x-axis. The front wheels 21, 22 have a distance between each other (wheelbase) of s_F, the rear wheels 23, 24 have a distance between each other of s_R. r_R designates the radius of the rear wheels 23, 24. The measuring entity 1 is arranged approximately in the center of a vehicle body 25 in a longitudinal direction. In a longitudinal direction, it has a distance l_F from the axle of the front wheels 21, 22 and a distance l_R from the axle of the rear wheels 23, 24.

[0026] The invention is not limited to wheeled vehicles having front-wheel steering. On the contrary, the rear wheels can also be steerable.

[0027] An exemplary embodiment for the arrangement shown in Figure 1 is illustrated in Figure 2. The acceleration measuring entity 3 is connected to the analysis entity 9 via a filter entity 5. The rotational speed measuring entity 4 is likewise connected to the analysis entity 9 via the filter entity 5.

[0028] The filter entity 5 illustrated in Figure 2 represents further filter entities which can be provided additionally in the case of the arrangements illustrated in Figure 1 to Figure 3 or in the case of modified arrangements. The filtering by the filter entities of measurement signals and/or signals derived therefrom is utilized in particular for eliminating any noises which might be present and for eliminating high-frequency fluctuations of the measurement

signals, e.g. caused by vibrations of the vehicle body. In particular, the filter entities can include at least one low-pass filter and/or at least one band-pass filter.

[0029] The filter entity 5 filters the acceleration signals which are measured by the acceleration measuring sensors of the acceleration measuring entity 3 and the rotational speed signals which are measured by the rotational speed measuring sensors of the rotational speed measuring entity 4, before these are transferred to the analysis entity 9.

[0030] As shown in Figure 3, the measuring entity 1 and the analysis entity 9 can be arranged together with further units and/or entities in a shared housing 2.

[0031] As illustrated in the figure, the analysis entity 9 can have a calculating unit 11 and a monitoring entity 10. The calculating unit 11 is used for calculating the relative movements of vehicle body and chassis. The monitoring entity 10 is used for monitoring the measurement signals which are generated by the measuring entity 1.

[0032] Using measurement signals of an angle of lock and a vehicle speed, which measurement signals are received via an input 6, the monitoring entity 10 carries out a monitoring of at least one of the variables measured by the measuring entity 1. For example, the monitoring entity 10 uses at least two angles (the angle of roll and the angle of pitch of the vehicle, which are obtained by integrating the rotational speeds) for monitoring the linear accelerations, said angles being a measure for the orientation of the vehicle in an

earth-fixed system of coordinates. In this way, it can take into consideration that the measured linear accelerations, depending on the orientation of the vehicle relative to the earth-fixed system of coordinates, contain a component which can be traced back to the gravity.

[0033] As illustrated additionally in Figure 3, the calculating unit 11 can be connected e.g. to a moderation regulating entity 12 in order to set a moderation of a spring suspension between the chassis and the vehicle body. Relevant information relating to such a travel situation can be output via an interface 13, to which e.g. the moderation regulating entity 12 is connected (and which alternatively can be connected directly to the calculating unit 11), to a system which utilizes the height levels and/or the linear accelerations measured by the measuring entity and/or rotational speeds as input variables.

[0034] The following now deals with an example for the calculation of the relative movement, said calculation being carried out e.g. by the calculating unit 11. A physical vehicle model is used in this case.

[0035] In this model, the vehicle body is considered to be a rigid body, i.e. no elasticities of the vehicle body are permitted. Allowance is nonetheless made for a spring suspension (in particular modulated) between the wheels and the vehicle body. Furthermore, three degrees of freedom of the relative movement between the chassis and the vehicle body are permitted, specifically a linear movement in the z-direction (e.g. the movement of a point, within the vehicle body, at

which the measuring entity measures), a first rotational movement about a first axis of rotation (in particular the x-axis) which runs horizontally through the vehicle, and a second rotational movement about a second axis of rotation (in particular the y-axis) which runs horizontally through the vehicle and perpendicularly to the first axis of rotation.

[0036] Figure 4 and Figure 5 illustrate the model schematically. A vehicle body 28 has center of gravity CG and is connected individually to the four wheels 21, 22, 23, 24 via springs 40, 41, 43 (only three of the four wheels are shown in the two figures) and via moderating elements 44, 45, 47 which act in parallel with the springs 40, 41, 43. Since the wheels 21, 22, 23, 24 are not directly mechanically connected to each other, it is also possible to speak of a five-mass model. The wheels 21, 22, 23, 24 stand on the subsurface 30 (e.g. a roadway). However, it has been shown that a two-mass model is equivalent to the five-mass model under certain conditions, wherein the wheels and further parts of the chassis form one mass and the vehicle body forms the other mass. Instead of the individual springs between the wheels and the vehicle body, consideration is given in each case to a single cumulative spring and (optionally) in each case an associated moderation for each of the three cited degrees of freedom. It is nonetheless possible to calculate the suspension travel or height levels at the four wheels individually using the two-mass model.

[0037] The following differential equations are solved in the context of the model:

$$\kappa_R \Delta\varphi + \gamma_R \Delta\dot{\varphi} = c_R a_y^{(e)} - \dot{\omega}_x$$
$$\kappa_P \Delta\vartheta + \gamma_P \Delta\dot{\vartheta} = -c_P a_x^{(e)} - \dot{\omega}_y$$
$$k\Delta z + \Gamma \Delta\dot{z} = -a_z^{(e)}$$

In this case, κ_R, κ_P, k are vehicle parameters which correspond to a linear spring force of the relevant movement component of the degree of freedom, γ_R, γ_P, Γ are vehicle parameters which correspond to a linear moderation term of the relevant movement component, c_R, c_P are further vehicle parameters, $\Delta\varphi$ is the relative angle of rotation between vehicle body and chassis about the x-axis (angle of roll), $\Delta\vartheta$ is the relative angle of rotation between vehicle body and chassis about the y-axis (angle of pitch), and $a_j^{(e)}, j = x, y, z$ are the effective linear accelerations in direction x, y, z as measured by the measuring entity which is arranged at the center of gravity of the vehicle body.

[0038] All parameters can be determined in advance e.g. experimentally and/or mathematically for a specific vehicle or a specific vehicle type.

[0039] The differential equations can therefore be solved (in particular numerically) and the movements in the three degrees of freedom $\Delta\varphi$, $\Delta\vartheta$ and Δz can be determined repeatedly (e.g. with a frequency of more than 100 Hz).

[0040] Application of the suspension travel equations

$$\Delta h_{FL} = \Delta z - l_F \Delta \vartheta + \frac{1}{2} s_F \Delta \varphi$$
$$\Delta h_{FR} = \Delta z - l_F \Delta \vartheta - \frac{1}{2} s_F \Delta \varphi$$
$$\Delta h_{RL} = \Delta z + l_R \Delta \vartheta + \frac{1}{2} s_R \Delta \varphi$$
$$\Delta h_{RR} = \Delta z + l_R \Delta \vartheta - \frac{1}{2} s_R \Delta \varphi$$

produces the suspension travels $\Delta h_j, j = FL, FR, RL, RR$ (the first index F signifies "front", the first index R signifies "rear", the second index L signifies "left" and the second index R signifies "right"), wherein s_F is the wheelbase of the front wheels, s_H is the wheelbase of the rear wheels, and l_F, l_R are the distances in an x-direction from the measuring entity to the front axle or the rear axle respectively, which distances have already been introduced with reference to Figure 6.

[0041] As mentioned above, this model presupposes the vehicle body to be a rigid body in itself, and is therefore suitable in good approximation for the travel of motor vehicles on roads. The model takes movements of roll and pitch into consideration as described above, and is therefore particularly suitable for travel situations and/or vehicles in which such movements occur. This applies particularly to

vehicles having a center of gravity which is positioned high above the chassis, e.g. in the case of trucks and rough-terrain vehicles.

[0042] In the above set of three differential equations, the following changes or alternatives can be implemented in particular:

- the springs can be described as non-linear springs,
- in one or more of the equations, in particular in the equation for the angle of pitch $\Delta\vartheta$, it is possible additionally to take into consideration a distribution of a braking force or braking forces and/or a driving force or driving forces (e.g. in the case of all-wheel driven vehicles) across the wheels, and/or
- the equation can be at least partially linked.